Computers and writing-tablets

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There has been a lot of recent publicity about the computer-based imaging techniques used to reveal barely visible traces of writing on the Dead Sea Scrolls. These are written in carbon-based ink and the image enhancement technique is photometric, building on the success of infra-red photography with long pass filters. We can effectively apply such techniques to enhance the writing on the ink-tablets from Vindolanda, near Hadrian's Wall, the papyri from Egypt, and the carbonized rolls from the Villa of Papyri at Herculaneum, with different degrees of success. At the Centre for the Study of Ancient Documents in Oxford (homepage address www.csad.ox.ac.uk), we are now working, in collaboration with the Department of Engineering Science, on new techniques to improve the legibility of documents written on wood and lead. These techniques are based on those developed in medical imaging for detecting signs of breast cancer and glaucoma.

Some scratches visible to the eye

Although much writing in antiquity was in ink, much was also merely scratched, and *incised* or scratched texts create an entirely different set of problems from those posed by ink-written texts. In the Roman world wooden writing-tablets were manufactured with the central surface recessed; the hollow panel was then filled with wax and the text was incised with a metal stilus. In virtually all cases of surviving tablets outside Egypt, Dacia, and Pompeii/Herculaneum, the wax has perished, and the surface now presents only the scratches made by the stilus as it penetrated the wax surface to the wood beneath. There are many dozens of these objects in museums in Britain and Europe. In particular, almost 200 have been found in recent years at Vindolanda, and it is these, now belonging to the British Museum, which we are using in our project. The number of texts incised on lead (the so-called 'curse-tablets') available to ancient historians has also increased rapidly in recent years. Only ten were known from Britain when the first Vindolanda stilus tablets were found; there are now some 250 – the most famous being those from the Temple of Sulis Minerva at Bath.

Some of the surviving documents are more or less legible without the assistance of sophisticated computer techniques. One tablet found in the Walbrook under the City of London was studied from high-contrast photographs. It is dated 14 March 118, and concerns the ownership of a wood called Verlucionium in what is now Kent.

The largest collection of lead curse-tablets, some 120 examples, was found by archaeologists in the hot waters of the Sacred Spring of Sulis at Bath. They are cylinders of lead or pewter, frequently oxidized and corroded, which must be carefully unrolled and cleaned, before they can be read. The incised text cannot be photographed satisfactorily, so the transcriber draws it, using an enlarged photograph as a guide, and working from the original with a binocular microscope and a raking light. The drawings are as honest as the transcriber can make them, but they are subjective and time-consuming. Ideally they represent what is there, no more and no less, without 'restoring' or completing any letters. A photograph would be inadequate, since it would miss some of each letter, depending on the angle of light, and it would include distracting irrelevances, such as the wood grain in stilus tablets or corroded areas in the lead curses. With practice, the transcriber supplies what has already been seen under another light-angle, and ignores what is 'irrelevant', before deciphering the text by testing a series of hypotheses – the art of decipherment is to read without inventing.

Coping with distractions

These examples represent a significant minority of surviving writing-tablets. There are many hundreds more on which it is possible to see that there is writing but virtually impossible to decipher more than odd letters here and there. It seems obvious that we ought to be able to use computers to help us read these texts more effectively, but the problems involved in three-dimensional imaging are very interesting and very challenging. The main factors rendering stilus tablets difficult to read are: (i) the scratches are shallow and they can often only be seen properly under intense low-raking light; (ii) the background on which the scratches are made almost always has a comparatively heavy wood grain that produces a distracting background texture; (iii) incidental and casual pitting further complicate the enhancement of writing; and (iv) as if the above were not already bad enough, a single tablet was often used more than once, thus offering two or more overlaid texts that need to be distinguished.

So, in order to help historians read stilus tablets more efficiently and to increase the quantity of tablets that can be read, wood grain and other distracting features like discolorations must be removed and features that correspond to incisions must be identified.

Luckily the wood grain usually is more or less uniform over the surface of a stilus tablet and it is relatively large compared to the incisions we are looking for. By aligning the camera appropriately when taking the pictures we arrange for the wood grain to be aligned with the horizontal and remove it by masking out certain components. The resulting images contain much less distracting information and are thus a great improvement for the human reader.

Incisions leap out

The technique that we have investigated to identify the incisions is called phase congruency. Consider carrying a torch on a dark night. Slight movements of the torch in the hand occasionally induce rapid movements of cast shadows, so that the object casting the shadow seems to 'leap out' from the background. The extent to which it does so depends on the orientation of the light beam relative to the surface orientation that casts the shadow and its separation in depth from the surrounding background surface. Importantly, surface discolorations, that can easily be confused with shadows in a single image, do not move. A simple qualitative technique (movement or not) suffices to discriminate between incisions and surface discolorations, but more detailed information will be needed to discriminate between incisions from two distinct sources (e.g. two 'authors', corresponding to two texts on a tablet used more than once).

In imitation of the 'manual' approach currently used by the historians we take a couple of pictures of the same stilus tablet with a light source moving in an arc 'over' the stilus tablet, beginning at a very low-raking angle (say 10 degrees above surface) and moving up in 5 degree steps.

Once the key features are identified in the individual images the output from all processed images is then combined in order to detect (i) the movement of certain features which corresponds to a moving shadow-highlight combination which moves as the light source is moved up and (ii) the fact that certain features do not move although the light source is moving. These then correspond to 2D features such as discolorations rather than the 3D features we are looking for. To date, we have used a simple correlation technique to discriminate surface discolorations (stationary features) from incisions (moving features). The results are very encouraging, giving a good classification and greatly reducing spurious responses due to 'noise'.

Testing on Tablet 836

Finally, by way of a progress report on a project which is still in its very early stages, we offer an illustration of one of the texts we have been working on, Vindolanda Tablet no. 836. This stilus tablet offers a unique opportunity for illustrating and testing the imaging techniques which are being developed with the use of variable directional lighting and phase congruency. Its uniqueness lies in the fact that, quite by accident, we are able to exploit images of the tablet captured in different states of preservation or conservation.

This was the only Vindolanda tablet to be discovered with the wax writing surface more or less intact. This was photographed, on site, at two different scales and we thus have two images of a single incised text on a relatively noise-free surface. During the conservation process the wax dissolved, leaving the bare wooden surface with the incisions made by the stilus where it penetrated the wax. It can be seen that, as in many cases, there are incisions not just from the text which we could see on the surviving wax, but from at least one other text as well. We have a photograph of the tablet in this state, taken with directional illumination.

Using these images we can produce coherent readings of parts of one of the texts written in this tablet. It should be emphasized that this text, on the wax surface, is relatively easily seen, but even so there are points at which the readings of the two historians differ and there is one area which offers particular difficulties and ambiguities. Letters printed in **boldface** are those which can be read with confidence.

banus bello suo salutem
(traces only)
acc_**erunt in uecturas**
de_arios octo **reliquos** solues
rios nouem qua__r_r__
sam dari debeb__
(interlinear addition?)
em libris
dus uale

'Albanus to his Bellus greetings ... they have received for transport 8 denarii. You will pay the remaining 9 denarii ... ought to be given (?) ... nine pounds (?) ... farewell.'

Looking at the lower image on p. 9 we can see which of the scratches belonging to the text transcribed above have penetrated the wax on to the wood so as to be visible under the different angles of lighting. We can also attempt to deduce which scratches from this text have not penetrated or are not visible; and which scratches survive that do not belong to this text but to another text.

Several problems remain to be addressed in the continuation of this research. The removal of wood grain has proved very useful for enhancing the image-quality for the human viewer; its usefulness for the incision-detection phase has still to be investigated, in particular since one can view wood grain as a form of discoloration (or shadows of very large extent moving in a very predictable manner) which could then be removed automatically using the stationary/moving classification outlined above. One technique is not only to move the light-source 'up and down' over the stilus tablet, but also 'around' it, i.e. in the same plane as the stilus tablet, thus highlighting features in different directions which are otherwise 'invisible'.

Eventually we should achieve a working technique which will make writing more easily legible. The key factor in any attempt to make a technological breakthrough with a very difficult problem is the application of different approaches and experience. The use of 'shadow stereo', described above, was originally developed in medical imaging, to measure the depth of the blind spot at the back of the eye. It is now being used as a central element in understanding and electronically replicating the perceptual processes involved in seeing, reading, and interpreting a text.

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